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TESTS OF BACK-SUCTION AND AIR-BLEED TYPE MIXTURE CONTROLS IN FLIGHT

(POWER PLANT SECTION REPORT)

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TESTS OF BACK-SUCTION AND AIR-BLEED TYPE MIXTURE CONTROLS IN FLIGHT.

OBJECT OF TESTS.

The object of these tests was to determine the effect on engine performance of several types of back-suction and one type of air-bleed carburetor mixture controls under actual flight conditions. From the results of these tests it was hoped that more satisfactory forms of control could be developed.

SUMMARY OF RESULTS.

All the "back-suction" controls tested proved to be sensitive and difficult to adjust. The uncertainty of readings obtained under flight conditions was apparent throughout the tests.

The following is a summary of the results obtained with the individual carburetors and controls:

TYPE "A" CONTROL.

Standard type 85-A back-suction control on Zenith U. S. 52 carburetor for Liberty "12" engine. The particular control tested appeared to be effective to an altitude of 19,000 feet. In service use, however, it has been found that different carburetors of the U. S. 52 type vary greatly, and many of the controls are not effective to such a high altitude.

TYPE "B" CONTROL.

Special back-suction control consisting of one valve piped to both Zenith U. S. 52 carburetors on a Liberty "12" engine. The flight tests of this control showed conclusively that at a certain point in its range the functioning of the carburetor was seriously interfered with, and the mixture could not be made leaner. It is believed that the flow through the compensator jet was reversed at this point.

TYPE "C" CONTROL.

Standard arrangement on Stromberg NA-D6 carburetor mounted on Hispano-Suiza model "H" engine. This control is only effective to an altitude between 12,000 and 16,000 feet, due to the excessively rich jet setting which is used on this carburetor.

TYPE "D" CONTROL.

Special two-way back-suction valve on Stromberg NA-D6 carburetor mounted on Hispano-Suiza model "H" engine. This control was effective to an altitude of somewhat less than 16,000 feet. Its action was quite similar to that of the type "C" control.

TYPE "E" CONTROL.

This was a Stromberg NA-D6 modified carburetor with standard control. The control is the same as type "C," but the main jet of the carburetor is reduced from No. 32 drill size to No. 35, thus increasing the actual effectiveness of the control. On test this appeared to be effective to something over 20,000 feet.

TYPE "F" CONTROL.

Standard air-bleed type control on old-style Packard double-venturi carburetor. Flight test indicated that control was effective to 20,000 feet. Since this is the only flight test conducted by the Engineering Division on this type of control, the results are open to question.

TYPE "G" CONTROL.

Air-bleed control on Packard double-venturi carburetor with special valve. Preliminary runs on the dynamometer indicated that this had no advantage over the standard Packard control, and it was therefore never flight tested.

TYPE "H" CONTROL.

Back-suction control with two-way valve on Packard double-venturi carburetor. This control proved to be entirely too powerful and too sensitive for practical use. It also interfered with the action of the compensator.

CONCLUSIONS.

From the results obtained the following conclusions are indicated, but it is believed that in order to check them with scientific accuracy the controls should be tested in a carburetor metering box equipped for simulating altitude conditions.

The back-suction type of control is too sensitive, i. e., at certain points a small change in the position of the control lever causes the engine to stop or slow down very suddenly.

By a good pilot, considerable saving in fuel at altitudes can be obtained, even with the back-suction type.

Sufficient depression can be obtained from above the venturi, in normal carburetors, to give adequate control of a single-venturi nozzle up to 20,000 feet.

Sufficient depression can be obtained from the throat of the main venturi to give adequate control of a double-venturi nozzle up to 20,000 feet provided the jet setting gives reasonably low fuel consumption at sea level.

It is not necessary for a control to be able to stop an engine, running wide open on the ground, in order to be sufficiently effective at 20,000 feet. Beyond this, no definite relation between performance of control on ground and at altitude has been established.

Insufficient experience with the air-bleed type of control has been obtained to reach any very definite conclusions as to its merits, but it is believed that the change in carburetor metering characteristics which is caused by a

change in the relative size of jet and air bleed constitutes a serious objection to this type of control, and its further development is not recommended.

In general, the back-suction and air-bleed types of mixture control are considered unsatisfactory, and the development of more promising types is recommended.

REFERENCES.

ENGINEERING DIVISION REPORTS.

1. Standard engine report of 12-cylinder Liberty motor, Serial No. 754, pages 21–23, inclusive.
2. Standard engine report of 8-cylinder Hispano-Suiza engine (300 horsepower), Serial No. 796, pages 21–23, inclusive.
3. Standard engine report on Packard model 1A–744 engine, Serial No. 1187, pages, 23, 24, and 26.
4. Instructions for installing 85–A mixture control in Zenith U. S. 52 carburetors, Serial No. 1385 (A. S. Information Circular, vol. 2, No. 175).
5. Report on tests to improve the Stromberg NA–D6 carburetor on the 300-horsepower Hispano-Suiza engine, Serial No. 1717 (A. S. Information Circular, vol. 4, No. 309).
6. The control of carburetor metering characteristics by the supplementary addition of air, Serial No. 1670 (A. S. Information Circular ,vol. 3, No. 292).
7. Report on the auxiliary air-port type altitude control as applied to Zenith carburetor, model U. S. 52, Serial No. 1811.
8. Instructions to pilots for the operation of mixture controls, Serial No. 1609 (A. S. Information Circular, vol. 3, No. 257).

DESCRIPTION.

For purposes of this report, the various types of altitude or mixture control have been designated alphabetically from "A" to "H," inclusive, and will be referred to by these letters throughout the report.

The Zenith U. S. 52 carburetor with type "A" control is manufactured by the Zenith Carburetor Co., of Detroit, Mich. The Stromberg NA–D6 carburetor with type "C" control and type "E" control is manufactured by the Stromberg Motor Devices Co., of Chicago, Ill. The Packard double-venturi carburetor with type "F" control was manufactured by the Packard Motor Car Co., of Detroit, Mich. All the other controls covered by this report were made and adapted to the corresponding carburetors by the shops of the Engineering Division.

Type "A" control was the standard 85–A control which is used on all up-to-date model U. S. 52 Zenith carburetors on the standard Liberty "12" cylinder engine. A description of this control may be found in reference No. 1. It is of the "back-suction" type, in which the mixture is made lean by opening a passage from above the venturi tubes to the float chamber and thus reducing the effective head on the jets. The float chamber is normally under air intake pressure by virtue of a connection between it and the top of the compensator wells, each compensator well being connected to the air space behind the venturis by a No. 17 drill hole. The flow of air from behind the venturis into the float chamber is restricted by a collar on the accelerating well tube. This method of restriction is believed to be at fault, since the accelerating well itself is rough drilled and the diameter varies between different carburetors. Small variations in the diameter of the accelerating well and the diameter of the collar on the accelerating tube make comparatively large variations in the effective areas of the restricting passage. It has been found in service that the effectiveness of controls will vary widely between a number of carburetors of this type.

Type "B" control was an experimental design supposed to correct the faults of type "A." Referring to Figure 1, it may be seen that this control consisted of a number of modifications on the standard U. S. 52 carburetor. On each of the two carburetors of a Liberty engine, a one-fourth inch copper "vacuum pipe" was led from the throat of each venturi to a point near the top of the float chamber. It was believed that the location of the end of these pipes at the throat of the venturi would make available a much higher suction than with the standard control and, therefore, a much more powerful control. Where the tube entered the float chamber a small drilled plug was provided to act as a restriction. The restriction hole at this point was No. 56 drill size in the first installation. The communication between the compensator well and the float chamber was cut off by means of a short section of brass tubing which was pressed into the upper end of the compensator well. Atmospheric pressure was communicated to the float chambers by means of three-eighths inch copper tubing. A section of this tubing was connected at each end to the cover of each float chamber. At the center of this same piece of tubing was a tee from which tubing of similar diameter led down to the control valve which was mounted on the side of the crank case of the engine. Another piece of tubing led from the control valve to the atmosphere, outside of the cowling of the engine compartment. The valve consisted of a flat circular seat with a hole which registered with the tube leading to the carburetors. A disk-shaped piece of brass formed the moving member of the valve. The edge of this disk was cut away as shown in Figure 1 so that in the full rich position the hole was fully uncovered and by moving the valve to the lean position the hole was gradually covered up. In the full lean position the hole was entirely covered. The space above the disk was closed by a cover through which the operating shaft of the valve extended to a lever connected to the pilot's control. The disk was held against its seat by a small spring. The atmospheric pipe was connected through the cover of the valve.

From the illustration and description the action of this valve is apparent. In the full rich position the valve is wide open, which allows atmospheric pressure to be communicated to the float chambers. The piping is sufficiently large, so that air drawn off by the suction pipes through the No. 56 restrictions was made up by air through the valve and piping without undue reduction below atmospheric pressure on the float chamber. As the valve was turned toward the lean position the atmospheric passage was progressively made smaller and the vacuum passages had a correspondingly increasing effect, until in the full lean position the float chamber was exposed to the full suction from the throat of the venturi and the flow of gasoline through the jets was thus greatly reduced or perhaps cut off entirely.

It was believed that this type of valve would have the following advantages over the 85–A control:

(*a*) Effective to greater altitude.

(*b*) Uniform between different carbureters, since the size of the atmospheric bleed hole and the vacuum holes could be held to close limits.

(*c*) Uniform in action between the two carburetors on the same engine, since both float chambers were bound to have the same pressure, due to the arrangement of piping.

(*d*) Smoother in action, due to the peculiar shape of the control valve disk.

Type "C" control was the standard control supplied on the Stromberg NA–D6 carburetor, which is described in reference No. 2. In addition, a sectional drawing of this control is shown in Figure 2.

Referring to the drawing, it will be seen that this is a "back-suction" control in which the float chamber receives atmospheric pressure through a restricted orifice communicating with the air intake of the carburetor just below the venturis. Suction is applied to the float chamber through a passage from the space back of the venturis. This space is under depression, due to four small holes drilled through each venturi at a point somewhat above the throat. The suction transmitted to the float chamber is controlled by a cylindrical valve, as shown. The capacity of the suction passage is supposed to be sufficiently large to overcome the effect of the restricted atmospheric vent in the full lean position.

Type "D" control, shown in Figure 3, is similar in principle to the type "C" control, in that it derives its suction from the space behind the venturis. The control valve, however, is a two-way valve with a flat disk, whose edges are notched in a manner exactly similar to the valve used in the type "B" control on the Zenith carburetor (see fig. 1). One port of the valve is connected to the space behind the venturis, while the other port is connected by copper tubing to the air intake of the carburetor. The space below the rotatable disk of the valve is connected to the top of the float chamber. In the full lean position the suction passage is wide open and the atmospheric passage closed. In moving from one position to the other the shape of the valve disk is such that one passage is opened gradually while the other is closed proportionately. It will be seen from this that the pressure in the float chamber is under the control of the pilot at all times between the limits of the pressure in the air intake and the suction behind the venturi. The normal atmospheric vent to the float chamber is plugged.

The object sought in the design of the above control was to provide a valve which would be extremely gradual in its operation and, therefore, be easy of adjustment. A further advantage is that there is no flow of air through the float chamber, and that the control has a wider range than type "C," due to the absence of a constant atmospheric vent to the float chamber.

Type "E" control was the standard NA–D6 arrangement used with a modified NA–D6 carburetor (see reference No. 5). In the modified carburetor the main jet is considerably smaller than in the standard carburetor, therefore a given setting of the control will give a leaner mixture in the case of the modified carburetor. It was therefore believed that the type "E" control would be effective to a greater altitude than the type "C."

The type "F" control was the standard control supplied on the Packard double-venturi carburetor for the model 1A–744 eight-cylinder engine. This control is described in reference No. 3, and Figure 4 also shows the standard control valve. It consists of a cylindrical sleeve, the inside of which is in communication with the atmosphere through two vertical holes drilled in the carburetor casting. In the full rich position this valve communicates with the main fuel passage by means of an extremely small hole, the function of which is to prevent syphoning of the gasoline from the emulsion well to the venturi nozzle. In moving the control valve toward the lean position a port in the valve comes into registry with the main fuel passage, thus allowing air to be drawn into the passage by virtue of the suction at the nozzle. The float chamber is vented to the atmosphere by a fixed orifice.

The theory of this control is that as the main fuel passage becomes vented to the atmosphere the nozzle will draw more air and less gasoline. It should be noted that this is in effect a variable air bleed, and from previous experience with carburetors of the air-bleed type such as the Stromberg it has been found that the relation of the air-bleed size to the main jet size has a marked effect on the metering characteristics of the carburetor. It is therefore to be expected that with this type of control the characteristic metering curve of the carburetor will change with different settings of the control valve.

Type "G" control, shown in Figure 4, was a modification of type "F." The cover of the float chamber was replaced by a disk valve very similar to the two-way valve used on the type "D" control except that the disk was cut away under the atmospheric port so that the space within the valve was always under atmospheric pressure. The other port of the valve was connected by a copper pipe to the top of the emulsion well. It was belived that the suction at the nozzle would draw air through this pipe in the same way that it would draw air in the standard type "F" control valve.

The advantages of this control over the standard Packard control were supposed to be as follows:

(*a*) Control much more powerful, since all passages for the atmospheric air were much larger.

(*b*) Gradual operation, due to shape of valve disk.

This control is still open to the objection that the metering characteristics of the carburetor will probably change with different positions of the valve.

Type "H" control is the back-suction, two-way type applied to the Packard double-venturi carburetor on the model 1A–744 engine. It is similar in principle to the type "D" control on the NA–D6 carburetor. The details are shown in Figure 5.

Referring to Figure 5, sections A–A and B–B, it will be seen that the standard cylindrical control valve was withdrawn from its passage. Hollow plugs, vented to the air intake by copper piping, were placed in either end of this passage to supply air to the compensator wells and to provide the small atmospheric vent to the main fuel passage necessary to obviate syphoning. Between the two plugs remained a cylindrical passage communicating by two vertical drilled holes to the bottom of the carburetor. These holes are normally vented to the atmosphere, but in the case of the control in question small brass pipes were added which curved around and terminated in an

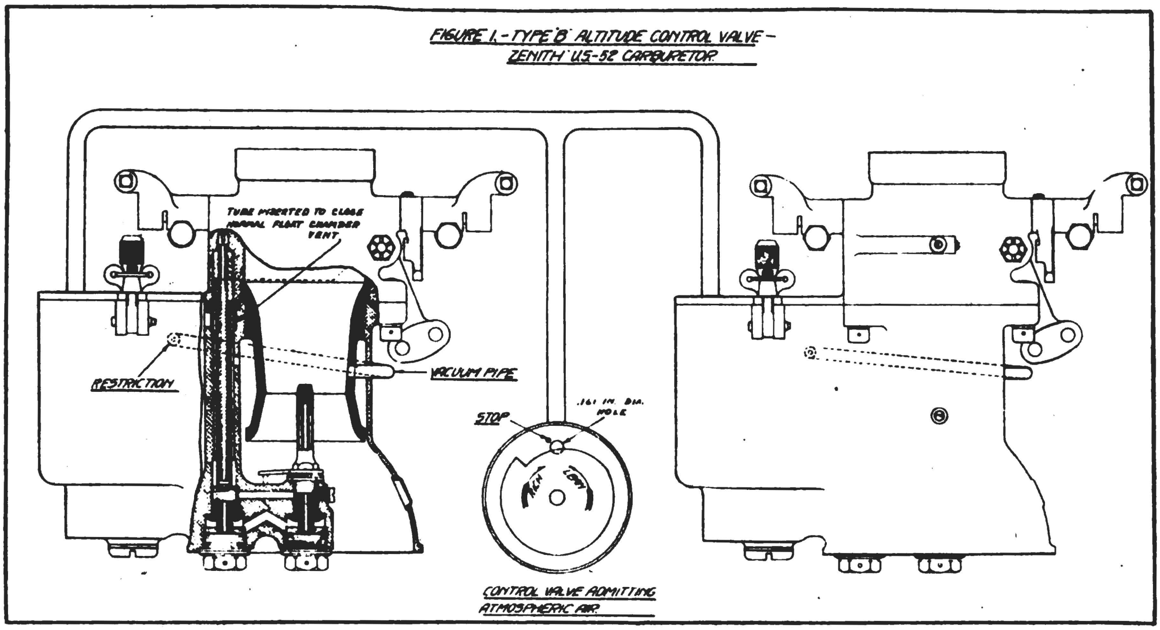

Fig. 1.—Type "B" altitude control valve—Zenith U. S.-52 carburetor.

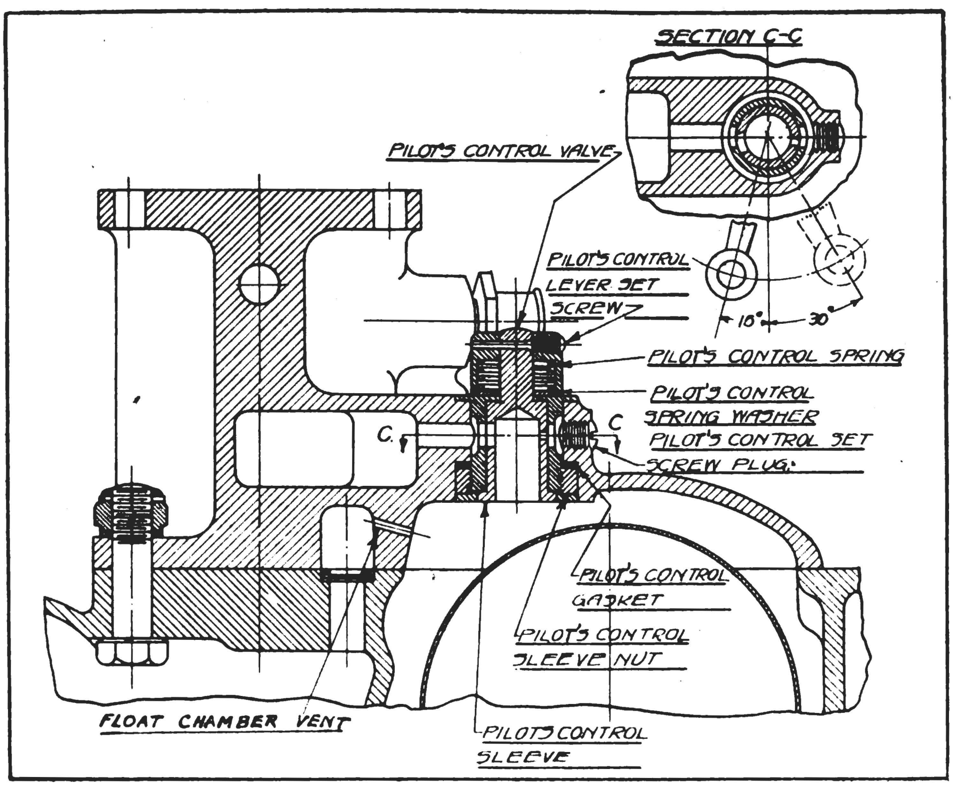

Fig. 2.—Type "C" Standard altitude control valve on Stromberg NA-D6 carburetor.

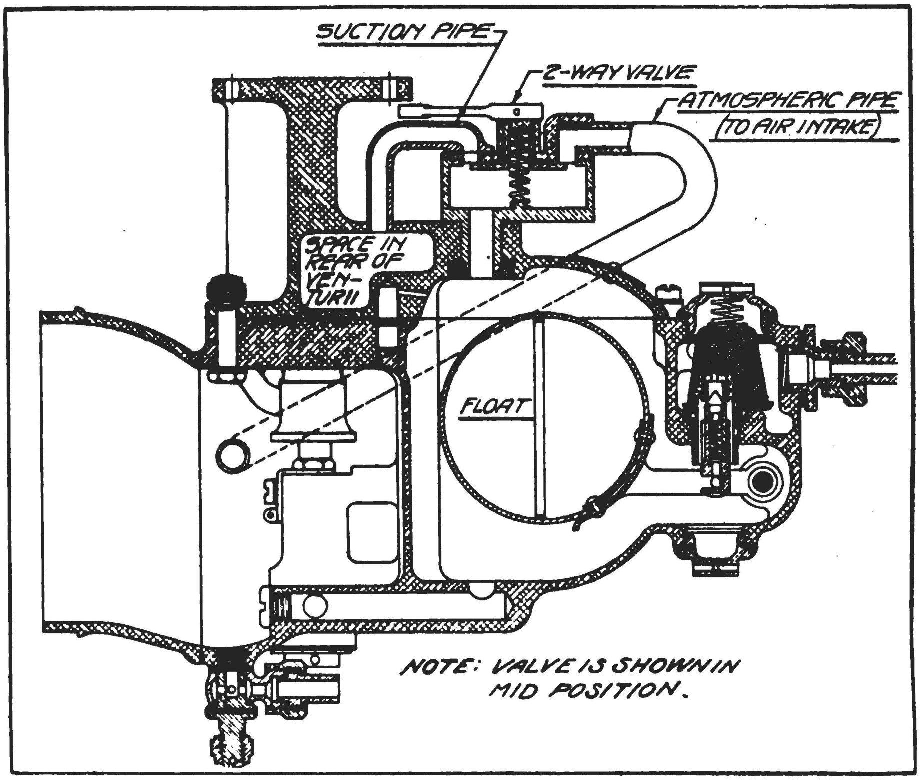

FIG. 3. Type "D" control applied to NA-D6 Stromberg carburetor.

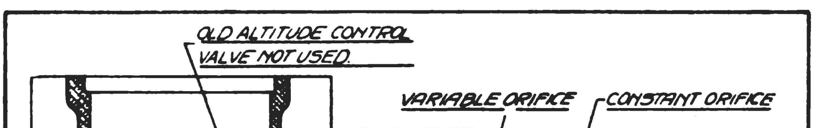

FIG. 4.—Type "G" control fitted to Packard carburetor on Packard Model 1A-744 Aviation engine.

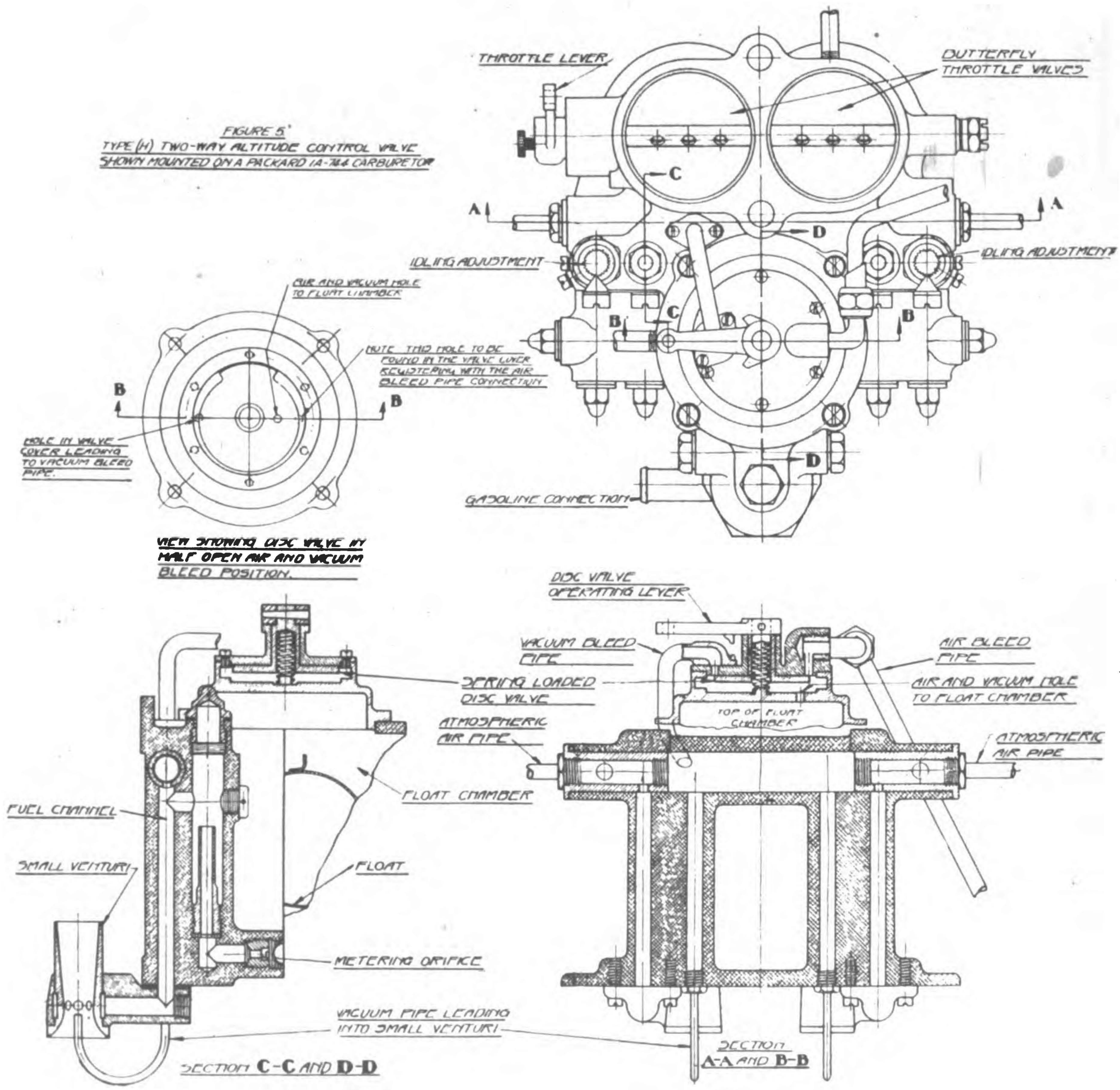

Fig. 5.—Type "H" two-way altitude control valve shown mounted on Packard 1A-744 carburetor.

open end at the center of each venturi nozzle. The horizontal cylindrical passage and the two vertical passages were, therefore, under constant suction transmitted to them by the small brass pipes communicating with the nozzles. The two-way control valve derived its suction from the horizontal cylindrical passage and its atmospheric pressure from a copper pipe leading down the side of the air intake. The valve disk was arranged for gradual opening as in the case of the valve disks previously described. The normal vent to the float chamber was plugged. In the full rich position the vacuum passage was entirely closed and the atmospheric passage wide open. This communicated atmospheric pressure to the valve chamber which was connected to the top of the float chamber through a hole in the bottom of the valve, shown in section B-B of the drawing. In the full lean position the opposite was the case, the atmosphere passage being closed and the vacuum passage being open. Sections C-C and D-D of Figure 5 show how the plug at either end of the horizontal passage communicated through a small hole with the main jet passage. Another view of Figure 5 shows the valve in mid-position with both the vacuum and atmospheric passages one-half open.

This design was made in an attempt to investigate the difference between the air-bleed and back-suction type of control on the same carburetor. It was designed as a very powerful control, as is shown by the fact that the suction was derived from the center of the venturi nozzle. With this suction fully applied to the float chamber and the atmospheric vent cut off, the flow of fuel through the nozzle would, in all probability, cease entirely.

METHOD OF TEST.

Each type of control was given a preliminary laboratory test to determine the action of the control, in various positions, on an engine running on the dynamometer. In each case the control was properly installed and the engine run at normal speed, full throttle, with the control valve in the full rich position. During this run readings of the revolutions per minute, brake load, float chamber vacuum, and fuel consumption were taken. With the engine still running, the control was shifted to the "best" position. The "best" position is defined as the leanest setting of the control which is possible without reducing the speed or power output of the engine. When this setting had been made, another run was conducted taking the same readings as before. The control was then shifted to the full lean position, and if the engine would still run the same readings were again taken.

In addition to the readings taken, these dynamometer runs served to show whether or not the engine was in good condition and gave a rough idea of the power of the control. The least powerful controls would cause very little drop in speed or brake load of the engine. Others caused a marked drop in speed and power, while still others would stop the engine entirely.

After the dynamometer test of each control it was installed on an engine mounted in an airplane and flight tested. Flight tests were designed to give the following information:

(*a*) Position of the lever for best setting at all altitudes from ground level to the service ceiling of the airplane,

(*b*) Action of the engine at several altitudes with the control set in the full rich, best, and full lean positions, respectively.

Most of the flight tests consisted of a climb at full throttle to service ceiling of the airplane, keeping the control lever set in the "best" position; that is, the leanest position which could be obtained without reducing the engine revolutions per minute. Readings were taken at intervals of 2,000 feet altitude of: Time after leaving the ground, engine revolutions per minute, position of the control lever, air speed of the airplane, and atmospheric temperature. In a few cases the flow of gasoline to the carburetor was taken by means of a Schroeder flowmeter and readings of the air temperature at the entrance to the carburetor "air scoop" were also taken on some of the tests. After climbing to service ceiling a level flight was made at full throttle with the control set successively at the best, full rich, and full lean positions. Under each of these conditions readings of the engine revolutions per minute, position of the control lever, and air speed were taken. Where possible, similar level flights were repeated at several suitable altitudes below service ceiling. For every test the lever in the cockpit which was connected to the altitude control valve was provided with a sector graduated in even divisions, and the position of the lever was indicated by the number of the division adjacent to it.

Many of the flight tests were incomplete due to various interferences such as unfavorable atmospheric conditions, trouble with mechanical equipment, etc. The extent of each test on any particular control and the results obtained may be determined by referring to Tables 1 to 13, inclusive.

ANALYSIS OF RESULTS.

In considering the results of the flight tests it should be remembered that the conditions under which they were made are not conducive to accurate results. For instance, the engine revolutions per minute is indicated by a tachometer which can not be read closer than 10 revolutions per minute. Furthermore, the engine speed under a given set of conditions will vary considerably with the attitude of the airplane, and although the pilot endeavored to hold the plane exactly horizontal during the level flights, this could not be done with absolute accuracy. Variations of 20 revolutions per minute may be expected due to this source of error. Another important source of error is the fact that there is no absolutely definite indication as to when the mixture control is set in the "best" position, due to the absence of an accurate method of observing the engine speed and to the fact that most of the controls were rather sudden in their action. Errors in setting the control lever, as great as 20 per cent of the lever travel, are probably present in most of the flight tests. These considerations should be borne in mind when analyzing the results obtained in the flight tests, and tendencies should be considered, rather than absolute values.

The results obtained in the dynamometer tests are considerably more accurate since the engine speed was taken by a positive counter, and comparatively accurate instruments for measuring torque and fuel consumption were used.

TYPE "A" CONTROL.

Referring to Table 1, it will be noted that the type "A" or Standard Zenith control effects a considerable reduction in fuel consumption over the full rich position when set in the "best" position. In the full lean position the engine speed was reduced approximately 400 revolutions per minute under dynamometer conditions and the running was irregular. Table 2 shows that the control was sufficiently powerful to reduce the speed of the engine even at 19,000 feet altitude. Referring to the level flight at this altitude, it will be seen that the engine speed for the best setting is 20 revolutions per minute higher than at the full lean setting. Results of this flight test are typical of an exceptionally good type "A" control. Due to irregularities in the mechanical construction of the Zenith type U. S. 52 carburetors, many controls of this type do not have sufficient power to reduce the speed of the engine above 15,000 feet. While the particular control tested is satisfactory with regard to effectiveness to a high altitude, it was reported as extremely sensitive and difficult to adjust. The general opinion of pilots throughout the Air Service is that this type control is unsatisfactory, due to the difficulty of adjustment and to the wide variation between different carburetors.

TYPE "B" CONTROL.

Referring to Table 3, the dynamometer test of type "B" control shows only a slight saving in fuel consumption of the best position over the full rich position. The control is evidently quite powerful, since the full lean position stops the engine. This control was tested on the dynamometer with vacuum restriction holes of No. 56 drill size, one in each vacuum pipe. The diameter of the atmospheric hole in the valve was 0.161 inch. Due to the seeming excess of power of this control, it was thought best to reduce the vacuum restriction holes before the flight test. One vacuum pipe was therefore entirely plugged, and one was reduced to No. 60 drill size on each of the two carburetors. The atmospheric hole in the valve was not changed.

The flight test shown by Table 4 revealed a peculiar characteristic of the type "B" control. At any altitude above 10,000 feet the control could not be moved beyond position No. 10½ without stopping the engine. The cause of this is undoubtedly a reversal of flow through the compensator jet, causing air to be drawn into the main fuel passage and thus cutting down the supply of fuel to the main jet to such an extent that the engine stops. This may be explained by the fact that the compensator well was not connected to the float chamber but was separately vented to the space behind the venturis. The compensator wells were therefore at approximately atmospheric pressure at all times. The pressure on the float chamber, however, was greatly reduced as the valve was moved toward the lean position and at position No. 10½ it is very probable that the float chamber pressure became so much lower than the pressure in the compensator well that air was drawn from the well into the main fuel passage. This defect in the control is a serious objection and makes it impractical for further consideration. The pilot also reported that the control was quite sensitive at the lower altitudes, before reaching position No. 10½.

TYPE "C" CONTROL.

Table 5 shows the results obtained from the dynamometer test of type "C" control. The NA-D6 carburetor is supplied with an unusually large jet for purposes of acceleration, which gives a high fuel consumption in the full rich position. This fuel consumption can be greatly reduced by moving the control to the best position as shown in Table 5. The control appears fairly powerful, since the engine power was reduced by nearly 50 per cent in the full lean position. The flight test of this control is covered in Table 6. Readings were not taken during the climb. The results show that the limits of the control was reached somewhere between 12,000 and 16,000 feet altitude, since at 12,000 feet a reduction in engine speed could be obtained by moving to the lean position, while at 16,000 feet the highest engine speed was obtained in the full lean position. For pursuit airplanes the control should be effective to at least 20,000 feet, and therefore this control is unsatisfactory in its present form. This type of control was reported less sensitive than the type "A" control on the Zenith carburetor, although both work on the same principle. It is believed that the presence of the compensator system in the Zenith carburetor accounts for its greater sensitiveness.

TYPE "D" CONTROL.

The results of the dynamometer test of type "D" control are not available, but it is believed that they would be similar to those obtained on the type "C" control, since the chief difference between the two is in the type of valve used. The location of the source of suction is the same in both cases, although the atmospheric vents are in different positions.

Table 7 shows that the type "D" control reached its limit of effectiveness at 16,000 feet or lower, since at this altitude the full lean position gave the highest revolutions per minute.

TYPE "E" CONTROL.

The dynamometer tests of type "E" control, Table 8, show this control to be considerably more powerful than type "C." This is to be expected, since the size of the main jet is smaller, and therefore the type "E" control, which is the same as type "C" in all other respects, will give a leaner mixture for a given setting of the lever.

The flight test covered in Table 9 shows that this control was fully effective at 20,000 feet, a drop of nearly 100 revolutions per minute being obtainable from the best to the full lean position. This control appears to be quite satisfactory except that it still retains the considerable sensitiveness inherent in the "back-suction" type.

TYPE "F" CONTROL.

Dynamometer tests covered in Table 10 show this control to have very little effect as a fuel saver and to have very little power, since the engine operation is only slightly affected by moving to the full lean position. The flight test covered in Table 11 shows that a drop in speed could not be obtained by means of this control above 20,000 feet. The limit of effectiveness is probably reached between 15,000 and 20,000 feet altitude. Since this is the only flight which has been obtained with this type of control, the results should not be considered as entirely conclusive. From dynamometer tests of car-

buretors equipped with this type of control the indications are that it is not nearly as powerful as the flight test results quoted in Table 11 seem to indicate. In this connection it should be noted that at an altitude of 5,000 feet a reduction of only 40 revolutions per minute is effected between the best and full lean positions of the control. Tests on many carburetors equipped with an air bleed to the main fuel passage have shown that the metering characteristics of the carburetor are greatly affected by a change in the relative size of the main jet and air bleed. It is considered safe to assume, therefore, that the type "F" control would give different metering characteristics of the carburetor at different settings of the control valve. This consideration leads to the conclusion that this type of control is not worthy of further development.

TYPE "G" CONTROL.

Dynamometer tests of the type "G" control showed it to be no more effective than the type "F" and flight tests were, therefore, not conducted.

TYPE "H" CONTROL.

The dynamometer tests covered in Table 12 show that some saving in fuel is effected by this control as between the best and full rich positions and that it will stop the engine in the full lean position. The flight test covered by Table 13 indicates an extremely powerful control, 4 divisions out of 10 being all that could be used at 20,000 feet. Referring to the level flight results, it will be seen that at this altitude the engine would stop in the full lean position of the control.

Results of this test are very similar to the results obtained on the test of the type "B" control. It will be noted that when position No. 4 was reached at 16,000 feet, the control could not be moved any farther with increasing altitude. This indicates that a reversal of flow through the compensator may have taken place in a manner similar to that which was indicated with the type "B" control.

The extreme power of this control could be remedied by locating the ends of the suction pipes at a position where the depression was considerably less than it is at the center of the venturi nozzles. The inherent sensitiveness of this type of control, together with the reversal of flow through the compensator, make it unsuitable for further development.

In conclusion, it is believed that results of these tests indicate so many inherent disadvantages of the back-suction control that serious consideration should be given to the development of controls working on entirely different principles. The auxiliary air-port control, preliminary tests of which are covered by references Nos. 6 and 7, appears to be a promising arrangement. This type of control has the great advantage over the back-suction type in that it does not interfere with the normal functioning of the various parts of the carburetor, such as the compensator jet. It should also be considerably less sensitive, due to the fact that a large volume of air must be handled and small movements of the control valve will not cause very large changes in the total volume of air passing through the valve. Another promising form of control is one using some method of changing the rate of flow of gasoline to the nozzles by mechanical means.

TABLE I.—*Dynamometer test of type "A" control (standard U. S. 52).*

Carburetor: Zenith U. S. 52.
Engine: Liberty. Model: 12A.
Date: July 15, 1920.

FULL THROTTLE RUN ON DYNAMOMETER.

Position of control valve.	R. P. M.	Corrected B. H. P.	Float chamber vac. in. H_2O.	Fuel cons. Lb. per hp. hr.
Full rich	1,730	404	6.2	0.537
Best	1,720	399	7.4	.513
Full lean [1]	1,300	230	6.2	.523

[1] Running unsteady in lean position.

Carburetor setting:
Chokes, 36 mm. diameter.
Main jets, 1.65 mm. diameter.
Compensating jets, 1.70 mm. diameter.

TABLE 2.—*Flight test of type "A" control.*

Airplane No.: DH-4, P-109.
Engine: Liberty "12."
Caburetor Zenith U. S. 52. Standard altitude control valve, type "A."
Propeller: 8-45.
Barometer: 29.276.
Ground temperature: 83° F.

FULL THROTTLE CLIMB TO SERVICE CEILING.

Time, min.	Alt., feet.	R.P.M.	Setting alt. control.	Air speed, M.P.H.	Flow-meter, inches.	Temperature. Strut. ° F.	Temperature. Air. Scoop, ° F.
....	0	1,540	0	....	5.4	83	90
1.15	2,000	1,620	0	65	5.5	70	82
3.10	4,000	1,630	0	63	5.5	61	79
5.25	6,000	1,620	0	66	5.2	54	77
8.00	8,000	1,600	0	65	5.0	48	70
11.00	10,000	1,580	1	63	4.7	47	73
14.45	12,000	1,570	3	63	4.7	40	70
19.20	14,000	1,550	5	60	4.4	30	62.6
27.00	16,000	1,530	9	58	4.0	22	61
42.30	18,000	1,520	11	56	3.8	10	48
56.35	19,000	....	12	....	3.7	....	....

LEVEL FLIGHT—SERVICE CEILING 19,000 FEET.

	R. P. M.	Setting alt. control.	Air speed, M. P. H.	Flow-meter, inches.	Fuel cons. gals. per hr.
Full throttle	1,550	Best, 12	....	....	....
	1,540	Rich, 0	....	....	....
	1,530	Lean, 15	....	....	....

LEVEL FLIGHT—ALTITUDE, 15,600 FEET.

	R. P. M.	Setting alt. control.	Air speed, M. P. H.	Flow-meter, inches.	Fuel cons. gals. per hr.
Full throttle	1,640	Best, 9	65	4.3	25.9
	1,640	Rich, 0	68	4.4	26.5
	1,240	Lean, 15	60	4.1	25.3

Remarks:
Altitude control, full lean at 15 divisions.
Lean position at 5,600 feet. Motor cut out.
Full throttle at 11,000 feet, revolutions per minute varying from 900 to 1,600 in lean position, 400 revolutions per minute less at same altitude; revolutions per minute steady, lean position.
Carburetor setting:
Chokes, 36 mm. diameter.
Main jets, 1.65 mm. diameter.
Compensating jets, 1.70 mm. diameter.

Table 3.—*Dynamometer test of type "B" control (valve on crank case).*

Four No. 56 drill size vacuum bleed holes; diameter of atmospheric hole in valve, 0.161 inch.
Carburetor: Zenith U. S. 52.
Engine: Liberty. Model: 12A.
Date: June 14, 1920.

FULL THROTTLE RUN ON DYNAMOMETER.

Position of control valve.	R. P. M.	Corrected B. H. P.	Float chamber vac. in. H_2O.	Fuel cons., lb. per hp. hr.
Full rich	1,720	402	4.0	0.548
Best	1,730	401	4.8	.544
Full lean	Engine stopped.			

Carburetor setting:
Chokes, 36 mm. diameter.
Main jets, 1.65 mm. diameter.
Compensating jets, 1.70 mm. diameter.

Table 4.—*Flight test of type "B" control.*

Date: July 8, 1920.
Airplane No.: DH-4, P-100.
Engine: Liberty 12A.
Carburetor: Zenith U. S. 52 type (B) control valve (air hole, 0.161 inch diameter 2 No. 60 drill size vacuum bleed holes.)
Propeller: 8-45.
Barometer: 29.36.
Ground temperature: 66° F.

FULL THROTTLE CLIMB TO SERVICE CEILING.

Time, min.	Alt., feet.	R. P. M.	Setting alt. control.	Air speed, M. P. H.	Flow-meter, inches.	Temperature.	
						Strut.	Air scoop.
						°F.	°F.
0	0	1,500	0	60	0	74	86
1.54	2,000	1,540	6	70	7	68	82
4.12	4,000	1,560	9	68	7	62	79
6.48	6,000	1,560	9½	68	7	52	72
9.42	8,000	1,580	10	67	6.8	48	68
12.36	10,000	1,600	10¼	68	5	38	54
16.00	12,000	1,560	10½	64	4.7	27	52
20.48	14,000	1,540	10½	62	5.2	24	52
28.42	16,000	1,540	10½	66	(?)	20	50
38.24	17,500	1,540	10½	62	(?)	10	50

Remarks:
Altitude control full lean at 15 divisions.
Impossible to get more adjustment above 10,000 feet without stopping engine.
Carburetor setting:
Chokes, 36 mm. diameter.
Main jets, 1.65 mm. diameter.
Compensating jets: 1.70 mm. diameter.

Table 5.—*Dynamometer test of type "C" control (standard NA-D6).*

Carburetor: Stromberg NA-D6.
Engine: Hispano-Suiza. Model: "H." Mfg. No. 19.
Date: June 21, 1920.

FULL THROTTLE RUN ON DYNAMOMETER.

Position of control valve.	R. P. M.	Corrected B. H. P.	Float chamber vac. in. H_2O.	Fuel cons., lb. per hp. hr.
Full rich	1,800	325	0.3	0.632
Best	1,800	324	11.0	.458
Full lean	1,800	174	18.0	(1)

[1] Back firing.

Carburetor setting:
Chokes, 1[illegible] inches diameter.
Main jets, No. 32 drill.

Table 6.—*Flight test of type "C" standard Stromberg control.*

Engine: Hispano-Suiza. Model: "H."
Airplane: XB-1A P-90.

Altitude, feet.	R. P. M., level flight.	Position of control.
20,000	1,620	[1] Best 10
16,000	1,680	[2] Best 7
	1,730	Lean 10
12,000	1,755	Best 6
	1,735	Lean 10
8,000	1,770	Best 5
	1,765	Lean 10

[1] Full lean.
[2] At 16,000 feet the pilot believed that he had the best setting at 7 points on control, whereas the best appeared to be full lean.

The control was divided in movement into 10 equal parts, numbered from 0 (full rich) to 10 (full lean).
The engine would not run in the full rich position at any altitude where a speed course was made.
Carburetor setting:
Chokes, [illegible] inches diameter.
Main jets, No. 32 drill size.

Table 7.—*Flight test of type "D" Engineering Division two-way mixture control.*

Engine: Hispano-Suiza. Model: "H."
Airplane: XB-1A, P-90.

Altitude, feet.	R. P. M., level flight.	Position of control.
20,000	1,610	Lean 10
	1,580	Rich 6
16,000	1,770	Lean 10
	1,745	Rich 4
12,000	No readings because of clouds.	

Best position was full lean.
Control movement divided into 10 equal parts.
The control was set full lean on the climb at about 11,000 feet, and at 12,000 feet on level flight it is believed that full lean was the best setting.
Carburetor setting:
Chokes, 1[illegible] inches diameter.
Main jets, No. 32 drill size.

Table 8.—*Dynamometer test of type "E" control.*

Carburetor: Stromberg. Model: NA-D6 (MOD).
Engine: Hispano-Suiza. Model: "H."
Date: May 23, 1921.

FULL THROTTLE RUN ON DYNAMOMETER.

Position of control valve.	R. P. M.	Corrected B. H. P.	Float chamber vac. in. H_2O.	Fuel cons. lb. per hp. hr.
Full rich	1,800	325	....	0.518
Best	1,800	322	....	.470
Full lean	Engine will not run.			

Carburetor setting:
Chokes, 1[illegible] inches diameter.
Main jets, 35 drill size.
Air bleeds, No. 46 drill size.

TABLE 9.—*Flight test of type "E" control on special NAD-6 (MOD.).*

Engine: Hispano-Suiza. Model: "H."
Airplane: XB-1A, P-90.

Altitude, feet.	R. P. M., level flight.	Position of control.
20,000	1,655	Full lean 10
	1,670	Full rich 2
	1,750	Best 4
16,000	1,760	[1] Full lean 8
	1,775	Full rich 2
	([2])	Best 4
12,000	1,715	[1] Full lean 7
	1,815	Full rich 2*
	1,820	Best 4

[1] Positions noted are leanest possible for smooth operation. Full lean was actually position No. 10.
[2] Pilot came down before reading was taken.

Control movement divided into 10 equal parts.
Carburetor setting:
Chokes, 1$\frac{1}{16}$ inches diameter.
Main jets, No. 35 drill size.
Air bleeds, No. 46 drill size.

TABLE 10.—*Dynamometer test of type "F" control (standard control on Packard carburetor).*

Carburetor: Packard double venturi.
Engine: Packard. Model: 1A-744.
Date: July 19, 1920.

FULL THROTTLE RUN ON DYNAMOMETER.

Position of control valve.	R. P. M.	Corrected B. H. P.	Float chamber vac. in. H_2O.	Fuel cons., lb. per hp. hr.
Full rich	1,605	184	0	0.475
Best	1,611	183	0	.474
Full lean	1,595	156	0	.466

Runs smoothly in full lean position.
Carburetor setting:
Chokes, 35 mm. diameter.
Main jets, No. 49 drill.
Compensating jets, No. 49 drill.

TABLE 11.—*Flight test of type "F" standard Packard control on Packard double-Venturi carburetor.*

Date: September 7, 1920. Hour: P. m.
Plane: P-144 Fokker.
Barometer: 29.428 in. hg.
Ground temperature 25° C.
Pilot: Sergeant MaDan.
Nature of test: Packard carburetor test.
Test No. 512-20.

Time, min.	Alt., feet.	R. P. M.	Setting alt. control.	Air speed, M. P. H.	Strut temp., °F.
0.8	2,000	1,750	2	80	65
2.3	4,000	1,740	3	80	55
3.8	6,000	1,740	3½	76	46
5.6	8,000	1,730	6	75	40
7.9	10,000	1,720	6	75	35
10.5	12,000	1,720	6½	74	30
13.8	14,000	1,690	6½	72	24
17.6	16,000	1,680	7½	70	20
22.2	18,000	1,680	9	68	12
28.3	20,000	1,660	10	65	2
38.7	21,800	1,620	10	60	5

Control full lean at 10.

TABLE 11.—*Flight test of type "F" standard Packard control on Packard double-Venturi carburetor*—Continued.

LEVEL FLIGHT—SERVICE CEILING 21,800 FEET.

	R. P. M.	Setting alt. control.		Air speed, M. P. H.
Full throttle	1,700	Best	10	72
	1,460	Rich	0	60
		[1] Lean		

LEVEL FLIGHT—ALTITUDE 20,000 FEET.

Full throttle	1,740	Best	10	82
	1,660	Rich	0	75
	1,740	Lean	10	[1] 82

LEVEL FLIGHT—ALTITUDE 15,000 FEET.

Full throttle	1,890	Best	8	110
	1,850	Rich	0	105
	1,820	Lean	10	102

LEVEL FLIGHT—ALTITUDE 10,000 FEET.

Full throttle	1,920	Best	3	128
	1,920	Rich	0	128
	1,900	Lean	10	128

LEVEL FLIGHT—ALTITUDE 5,000 FEET.

Full throttle	2,000	Best	0	140
	2,000	Rich	0	140
	1,960	Lean	10	136

[1] Same as best.

Remarks: As a whole, control does not affect revolutions per minute very much. Smoothness of operation is obtained, however, by its use (at high altitudes).
Carburetor setting:
Chokes, 35 mm. diameter.
Main jets, No. 49 drill.
Compensating jets, No. 49 drill.

TABLE 12.—*Dynamometer test of type "H" control (two-way back-suction valve on Packard carburetor).*

Carburetor: Packard double venturi.
Engine: Packard. Model: 1A-744.
Date: July 20-21, 1920.

FULL THROTTLE RUN ON DYNAMOMETER.

Position of control valve.	R. P. M.	Corrected B. H. P.	Float chamber vac. in. H_2O.	Fuel cons., lb. per hp. hr.
Full rich	1,608	182	0.4	0.505
Best	1,605	179	.4	.474
Full lean	Engine stopped.			

Carburetor setting:
Chokes, 34 mm. diameter.
Main jets, No. 49 drill.
Compensating jets, No. 49 drill.

Table 13.—*Flight test of type "H" control on Packard double-venturi carburetor.*

Date: September 13, 1920. Hour: P. m.
Plane: P-144 Packard Fokker.
Barometer: 29.27 in. hg.
Ground temperature, 77° F.
Pilot: Sergeant MaDan.
Nature of test: Carburetor test.
Test No. 512-20.

FIRST FLIGHT WITH TYPE "H" CONTROL.

Time, min.	Alt., feet.	R. P. M.	Setting alt. control.	Air speed, M. P. H.	Strut Temp., °F.
0	0	0	0	0	0
1.2	2,000	1,720	2	76	70
2.7	4,000	1,700	2½	76	60
4.4	6,000	1,700	2½	74	53
6.4	8,000	1,700	3	70	50
8.6	10,000	1,670	3	70	45
11.2	12,000	1,660	3	68	38
14.6	14,000	1,660	3	68	32
18.0	16,000	1,650	4	66	25
25.5	18,000	1,640	4	64	20
36.0	20,000	1,600	4	60	9

Control full lean at 10.

Table 13.—*Flight test of type "H" control on Packard double-venturi carburetor*—Continued.

LEVEL FLIGHT—SERVICE CEILING 20,000 FEET.

	R. P. M.	Setting alt. control.	Air speed, M. P. H.	Strut Temp., °F.
Full throttle	1,650	Best 4	76	9
	1,650	Rich 0	76	9
	Cut out.	Lean 10	....	....

Remarks:
Altitude adjustment too sensitive; at 20,000 feet, one sixty-fourth of an inch either way from best adjustment will lose revolutions per minute.
Control full lean at position 10.
Carburetor setting:
Chokes, 34 mm. diameter.
Main jets, No. 49 drill.
Compensating jets, No. 49 drill.